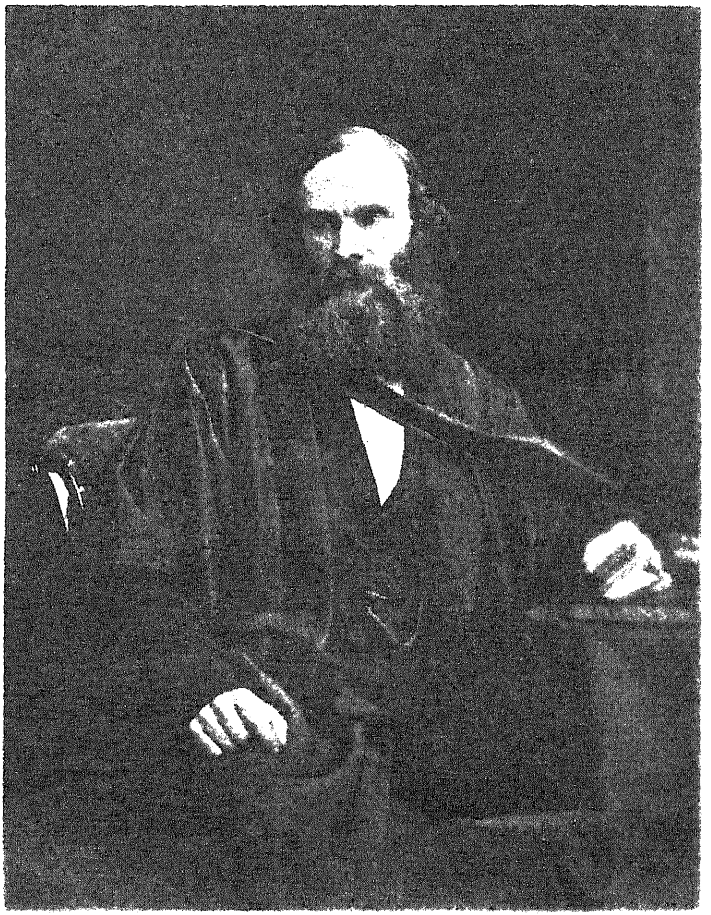

COLLECTED PAPERS

IN

HYSICS AND ENGINEERING

BY

AMES THOMSON, D.Sc., LL.D., F.R.S.

PROFESSOR OF ENGINEERING IN QUEEN'S COLLEGE, BELFAST
AND AFTERWARDS IN THE UNIVERSITY OF GLASGOW

LECTED AND ARRANGED WITH UNPUBLISHED MATERIAL
AND BRIEF ANNOTATIONS BY

JOSEPH LARMOR, D.Sc., LL.D., SEC. R.S., M.P.

UCASIAN PROFESSOR OF MATHEMATICS IN THE UNIVERSITY OF CAMBRIDGE

AND

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PREFACE

IT is well known—chiefly through references to his work by other physicists such as his brother Lord Kelvin, Thomas Andrews, James Clerk Maxwell, Osborne Reynolds, J. Willard Gibbs—that the scientific activity of James Thomson has left permanent marks on the history of several branches of physical science. The collection into readily accessible form, in one volume, of his published contributions to knowledge, has thus been desirable, especially in view of the scattered local journals, often remote from modern facilities for reference, in which much of the work originally appeared. The project of a posthumous collection of his brother's work was constantly encouraged and looked forward to by Lord Kelvin during his later years, but his numerous pre-occupations prevented active assistance.

On the recent completion of the Collected Edition of Lord Kelvin's own scientific work, the idea has impressed itself on others that there should be available a full record of the work—very different in general type from his own—of his brother who was his lifelong companion and scientific associate. The materials for the present collection have been brought together mainly by the care of his son, James Thomson, of the Elswick Engineering Works, Newcastle-on-Tyne, assisted zealously by his wife who has not survived to see the completion of her work; while the Biographical Memoir, containing passages of high interest as regards the personal aspect of the progress of Physical and Engineering Science in this country in the middle of the last century, has been constructed largely out of narratives and recollections obtained by his daughter Mary Hancock Thomson.

Letters of scientific importance which passed between Lord Kelvin and his brother, on subjects such as the Theory of the Dissipation of Energy and the characteristics of natural flow in liquids, have been included, as well as scientific correspondence with Faraday, Clerk Maxwell, Andrews, H. C. Sorby and other eminent men.

The main characteristic of James Thomson's mind was the marked originality of his way of looking at scientific problems, arising in part perhaps from a combination, then more common than now, of the abstract physical with the practical engineering interest, but also fostered by the independent and unconventional character of his scientific education. This quality was united with singular persistence in brooding over a train of thought, and following it out into all relevant details and ramifications. So constantly was he pre-occupied with the various aspects of his scientific problems, as to sometimes produce an impression that his whole life was concentrated in one absorbing interest. But in the published expression of his results, at any rate, he was usually concise. The assemblage in 500 pages of so much pioneering insight in so many subjects recalls in some respects the work of even the most original of physicists. In many of these subjects discovery and invention have of course progressed far beyond what was feasible when these notes and papers were concerned often with breaking almost new ground; the recent great development of water-turbines for the electric utilization of hydraulic power in mountainous regions is a case in point. But in the main these papers are in no sense obsolete; their acute direct scrutiny of phenomena is of interest to the mathematical physicist by way of contrast and supplement to his own procedure; and where appositeness to practical application may have failed through lapse of time, their relation to the history of science takes its place.

Other examples of the topics treated in these papers may be mentioned. In the first rank there is his own cardinal discovery of the lowering of the freezing point by pressure, which ramifies on one side into the subject of the influence of stress on solution and crystallisation, and on the other into acute observations on the formation of ice in nature, the ground ice of the St Lawrence, and

the glacial origin of the Parallel Roads of Glenroy. The investigations on the natural flow of water and its measurement are fundamental in the practical science of hydraulics. He also devoted lifelong attention to the problems of the general atmospheric circulation, summing up in the Bakerian Lecture compiled in the last year of his life. Again, his close association as a colleague with Thomas Andrews, at the time when the latter was occupied by his classical researches on the continuity of the gaseous and liquid states of matter, led them to the well-known developments concerning the unstable regions in the Andrews diagram, on which much new matter has now been added from unpublished manuscripts. The remarkable early papers on elasticity, on the influence of intrinsic strain on the strength of materials, on the dynamics of spiral springs, have remained prominent through Lord Kelvin's expositions. In his later years the foundations of abstract dynamics, in connexion with the fundamental characteristic of relativity, led to fresh and original papers, which have regained interest from the wider physical discussions now prevalent on that subject.

The Editors desire to record their thanks for much valuable assistance received, as regards the printing of the volume, from the staff of the Cambridge University Press.

J. L.

CAMBRIDGE,
July 1912.

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THE late Professor James Thomson, during his long and active life, wrote numerous scientific papers which were read before the Royal Societies of London and Edinburgh, the British Association, the Philosophical Societies of Belfast and of Glasgow, and other learned bodies; but, scattered in a fragmentary manner through the Proceedings of many different Societies, they have not hitherto been easy of access. It has been thought desirable that the fruit of his activity should be collected and reprinted consecutively in a single volume.

His life is a record of long days spent in the search for truth, and of the ample reward in new knowledge gained. The fundamental character and value, to science and to engineering, of the discoveries and ideas which he has given to the world, is the feature of his work.

James Thomson and his brother William (afterwards Lord Kelvin) are striking examples of hereditary talent; and it would have given their father much happiness could he have foreseen how fully his own best qualities, as well as those of his beloved wife, had been transmitted to their children. In fact one cannot completely understand either of the two sons without knowing something of their father.

Descended from a long line of farmers who had originally migrated from Scotland to the North of Ireland early in the 17th century (about the time of the Plantation of Ulster), he inherited those sterling Scottish qualities which have made Ulster men so successful in turning the resources of their province to good account. At the same time he acquired the softer qualities characteristic of his Irish neighbours.

A letter from one of the family states that "they nearly all bore the character of being religious, moral, patriotic, honest, large, athletic, handsome men." They had occupied for 200 years a farm called Annaghmore, near Ballynahinch in County Down, 14 miles from Belfast, and within sight of the noble range of

the Mourne Mountains. Here, in 1786, James Thomson, s(ior, was born.

The country in the immediate neighbourhood, like th: of County Down generally, is fertile and undulating; the hil cks are so peculiarly rounded that their appearance has been ;)tly likened to a basket of eggs. Between these hillocks one ads little valleys with glancing streams and green copses, and s(ne- times a clear lakelet lies open to the sky. Low-lying bogs are few; and drainage has converted into rich meadowland n ny swamps that were formerly tenanted only by the coot and s1 pe. A Spa attests the fact that health-giving springs abound; nd when the South wind blows it brings with it the ozone from he sea.

James Thomson, senior, the first of the family to l(ve agriculture for scientific pursuits, was a man of remark:)le ability. When quite a young boy, having received only he rudiments of education by the teaching of his father, he m de out for himself the art of dialling without the aid of teacl rs or good books. He thus succeeded not merely in makin; a sundial, but also a dial to tell the time at night by one of ie stars of the Great Bear. He used to tell his children how ie had puzzled over an old book on navigation which containe a chapter on dialling, and felt disheartened because he could)t understand it; and how he subsequently found that his difficul es had arisen from the fact that the book was all wrong. One ni; it sitting up with his father and elder brother, Robert, to guard t e orchard, while he watched the stars slowly revolving he thou; t out for himself the true principle of dialling, and made a dial r his father's farm which told the time correctly. Robert's son, Hu; , used to give the following account of his youthful discovery: - "While the ploughing of a field was going on Robert and h little brother, James, then about eleven years of age, rested times. The boy was then observed to be working with a sla and a bit of stone for a pencil. In the evening after they can home, again he began to work, having brought in a handf of shavings from the workshop to make a blaze till the candl should be lighted. After a little the boy exclaimed to his brothe 'Robert, I have made a discovery, I have found out how to mak dials for any latitude.' 'Can you show me?' said Robert, an he showed it so clearly that his brother understood it quite well.

Two of these rough sundials and a star dial are now in the possession of his grandson, James Thomson.

His early progress in Mathematics was remarkable. His father allowed him to go to Dr Edgar's school at Ballynahinch, where he very soon made himself useful as a teacher; and then for four years, from 1809 till 1814, he studied at the University of Glasgow, taking his degree of M.A. in 1812. He then attended the classes of Theology and became a licentiate in the church of Scotland; and he also commenced the study of Medicine; but on the foundation of the Royal Belfast Academical Institution, he was elected to the chair of Mathematics, and returned to Ireland. He taught in Belfast from 1814 till 1832, when he was appointed Professor of Mathematics in the University of Glasgow. He wrote a number of important and successful school books on Arithmetic, Geography, Trigonometry, and higher mathematical subjects. The first of these was brought out in 1819, and new editions have been in wide circulation up to the present day. His books reveal originality, and constructive as well as analytical power, qualities which we find transmitted to most of his children, but particularly to his two eldest sons, James and William. The gentleness, ready wit, charm of manner, and warm-heartedness characteristic of all three, stamped them as partly Irish in spite of the Scottish blood in their veins.

In 1816, Margaret Gardner, a young, bright and lively girl, came from Glasgow to Belfast, to visit her relations, Dr and Mrs Cairns, who were friends of James Thomson; and the young professor, then 30 years of age, was much attracted to her. She was a daughter of William Gardner, a merchant in Glasgow, who had fought on the British side in the American War of Independence. His watch, which is preserved in the keeping of one of his great-grandchildren (Agnes Gardner King), shows the dint of a bullet which the strong case of the watch saved from piercing his heart. An extract from one of Miss Gardner's letters to her sister, Agnes, afterwards Mrs Gall, gives interesting impressions of Belfast and the people who lived there in 1816.

"*July* 1816.

On Tuesday last we spent a most agreeable day at a Dr Drennan's*. This has been our longest walk. It is more than three miles in a most beautiful part of the country, but

* Cabin Hill, near Belmont.

indeed every way you can turn the country here is fine and alw /s something new; the party was ourselves, Miss Reid, and Profes or Thomson. I never saw a more agreeable family. The Dr i a gentleman retired upon a small fortune; he and his wife dev e their time almost entirely to the education of their family. S e has been a beautiful woman and is said to be very accomplish l, and the children from the little we saw of them seem to rep y the pains taken in their education. It is just such a place s one would wish for, in the cottage style, white-washed a l thatched roof, but containing a good house within; not fi , but neat and comfortable, upon the side of a hill well shelter l with trees; commanding to the front an extensive view of t e surrounding country, to the back the Loch with its cultivat l shores, and the Cave Hill which is a rugged mountain that forr s the termination to a range of hills on the other side of Belfa . Belfast was hid in the valley between, but its smoke showed whe e it stood. A very fine day and the season of the year gave these beauties their full charm; agreeable company and goc spirits made us enjoy them. But they are far above descriptio ; so I leave you to fancy the Loch smooth as a lake, vessels sailir in different directions, mountains sloping into green hills ar fertile plains, etc.

Everything about the grounds showed the 'touch of taste We walked about them all the afternoon and came home b moonlight, all agreeing we had spent a most agreeable da I had the honour of the Mathematician as my walking companio His first appearance is about as awkward as can be; he looks a if he were thinking of a problem and so modest he can scarcel speak, but when tête-à-tête he improves amazingly in the wa of speaking. On our forenoon walk we had a most edifying an feeling discussion on sea-sickness and the best mode of preventin it. But in the evening we were much more sublime. I suppos the moon rising in great beauty, and Jupiter shining with un common lustre, called forth the Professor's energies, and I got very instructive and amusing lecture upon astronomy."

In the following year Margaret Gardner married the "Mathematician," and she became the mother of a family of seven children*, of whom James, the subject of this sketch, was the third child and eldest son, and William, afterwards Lord Kelvin, the next in age.

* Elizabeth, Mrs David King, born 1818, died 1896.
Anna, Mrs William Bottomley ,, 1820, ,, 1857.
James ,, 1822, ,, 1892.
William, Lord Kelvin ,, 1824, ,, 1907.
John ,, 1826, ,, 1847.
Margaret ,, 1827, ,, 1831.
Robert ,, 1829, ,, 1905.

She was gentle and refined, pious and truthful, and with a strong sense of humour. She directed her household with the courage, energy, perseverance and practical commonsense so characteristic of the Lowland Scots; and it was a dire calamity to her husband and to the young family, when death carried her off a year after her youngest son, Robert, was born. All this and much more about the influences which moulded the minds and characters of Professor James Thomson's young family has been gracefully told by Elizabeth King in her book on *Lord Kelvin's Early Home**.

James was born in Belfast on February 16th, 1822, and his brother William two years later. They both developed early a zeal for knowledge, and were encouraged in this by their father who educated them himself with tenderest care. In fact during these early years he was both father and mother to them, and they never forgot it.

In October 1832, their father removed with his family to Scotland on his appointment as Professor of Mathematics in the University of Glasgow. Their home was in the Professors' Court of the old College in the High Street, a fine historic group of buildings, but situated in what had even then become a very undesirable part of the city.

The College session lasted for six months, from the 1st of November till the 1st of May. The long summer holidays enabled the professors to live with their families during a considerable part of each year in more healthful and congenial surroundings. Professor Thomson used to rent a house in the Island of Arran, at some place on the Firth of Clyde, or on the coast of Ayrshire. There the boys had sea-bathing, learned to swim and to row, and sailed toy boats which they made and rigged themselves. Thus they lived a healthy, active life in summer, spending some hours each day at lessons with their father. James and William were, then and always, devotedly attached to each other. From their earliest childhood they were closely associated; all through their youthful days, in their studies and their amusements, they were constantly together. Certain characteristics of the two brothers were noticed even when they were boys, which remained through life. James was the more careful and exact, and William the more quick and ready. For

* Macmillan and Co. 1908.

till his boat was finished with the utmost perfection in every detail even to the neat painting of it; William was content as soon as he had his boat finished enough to be able to sail, and would not spend more time and trouble over it. In after years, James, before publishing a scientific paper or bringing out one of his inventions, had the whole thing long and carefully thought over. His theories thus stood the test of investigation, and his machine or engineering structure could be relied on to do exactly what it was intended to do. On the other hand, his brother William's less patient scientific work was often thrown off at white heat, and thus subject to frequent correction and adaptation by its author.

At the ages of twelve and ten respectively they entered Glasgow University together, and they very soon distinguished themselves in every subject they took up. The younger brother, who was even then adored by all the family as a genius, generally took the first place and James the second. No cloud of jealousy ever marred the friendship of the pair. The elder sympathised with his father in the affectionate pride he took in the ability of the younger; and the younger was ready at all times to check his own impetuosity by laying his ideas before the elder brother for criticism or advice. They were unusually young, even for those days, to be at a University; but there was a reason for it. Owing to a misunderstanding as to the amount of the emoluments of his Chair, their father found himself in a very bad position financially during the first years of his residence in Glasgow. He could not afford to send his sons to school. Instead of this being a misfortune, the two sons looked upon it as a very happy circumstance for them; and they always rated very highly their obligations to the early grounding their father had given them.

At this time Professor James Thomson, senior, was engaged in writing his Mathematical books; and he also found time to conduct a class on Astronomy, to which ladies were admitted —a novel departure at that time. This strenuous life prevented him from taking much part in the social life of Glasgow; but it gave his wife's relations (her cousins Mr and Mrs Walter Crum of Thornliebank, in particular) an opportunity of showing much kindness to the motherless family. The intimacy thus begun with the cousins was to be cemented later by the marriage of

their daughter, Margaret, to William Thomson in 1852; while James owed much of the encouragement he received for his early inventions to her father's and brother's kindly interest.

In 1840 James Thomson took his degree of M.A. with honours in Mathematics and Natural Philosophy. In the holidays of 1839 and 1840, their father had taken the young family to the Continent, spending some time in London *en route*. They thus gained some acquaintance with the French and German languages, and with the general culture, manners and customs of foreign nations. The diaries kept by James show the keen interest they took in all they saw. Mechanical inventions and appliances especially interested them.

They also much enjoyed going to the theatres with their father's friends, and visiting museums, galleries and exhibitions. Macready in *Henry V* made a lasting impression on them; Robert Rintoul (the son of their father's friend, Mr Rintoul, Editor of the *Spectator*) took the young people to this performance. Another friend of their father, Mr Knowles, of the same family as Sir James Knowles, the late Editor of the *Nineteenth Century Magazine*, is also mentioned in the diary.

The greater part of the first year's visit was spent by the boys in Paris, while their father went with his two daughters to Switzerland. The next year they all went to Germany, sailing up the Rhine through Holland. While they were staying in Bonn in June 1840, Professor Nichol* and his family joined them. He took James and William for a three days' geological tour among the hills. At Königswinter they were joined by all the rest of the party. The Drachenfels, and especially the sail up the Rhine to Nonnenwerth by moonlight, made a strong impression on this company of happy young people. This is how one of them, John Nichol†, wrote about it in after years:

"'It was upon a trancéd summer night' that we sailed round the corner of the Rhine which reveals the Siebengebirge, and came gliding into the island of Nonnenwerth. Clear and calm and fair the memory of that night comes back to me from over all the years. One by one the peaks appeared, and stood grandly above the quiet stream, in the grey light which soon faded away

* John Pringle Nichol, Professor of Astronomy in the University of Glasgow, 1836—59.

† John Nichol, Professor of English Language and Literature at the University of Glasgow, 1862—89.

beyond their purpling crests. The moon stood out, a glorious crescent on the ridge of Rolandseck, and a bright star led the host of heaven over the brow of Drachenfels. The lights of the little convent were twinkling through the trees, and the boatmen were chanting their evensong as they came and brought us to the shore, where we stepped hand in hand together to live what seems to me like a dream of the gates of heaven. If my summer on the Rhine is an oasis in my life, Nonnenwerth is the oasis within the oasis, the greenest and most beautiful spot amid the whole of this enchanted ground*."

More than sixty years later, when Lord Kelvin came to visit his nephew in Newcastle-on-Tyne, and his father's diary of this little tour was shown to him, this was the incident that caught his attention; and he enlarged upon it in such a way that those who listened felt that he loved to dwell on it.

Shortly after this, James unfortunately injured his health when walking with his brothers William and John in the Black Forest. He hurt his knee in some way, but did not complain at the time. He had already decided to adopt Civil Engineering as his profession, and, after his return from Germany, he entered Mr (afterwards Sir John) McNeil's office in Dublin, but in three weeks ill health obliged him to give up work and he returned home quite lame. He had a good friend in John R. McClean, who afterwards attained a great position in the early days of railway construction. They had been fellow students in his father's class, and McClean had been one of the Professor's favourite pupils.

A characteristic letter of McClean's refers to one of James's earliest inventions, a boat which, by means of paddles actuating jointed legs reaching to the bottom, is able to propel itself up a river—walking against the stream.

"WALSALL, 15*th Nov.* 1841.

MY DEAR JAMES,

I was much gratified at receiving your note of the 6th Inst. and if it had been longer would have relished it still more. Whenever you have leisure I will feel obliged by your writing me a few lines. I regretted much not seeing your father when he was in England and also your postponing your visit, but I will hope to see you in Spring for some months when we may be mutually serviceable. I am glad to find that you will be able to attend the Civil Engineering Class this session—no doubt you

* See *Memoir of John Nichol*, p. 26 (MacLehose and Sons).

will derive much benefit from it. If Mr Gordon* has published the heads he proposes lecturing on, I will be much obliged by your sending me a copy by post.

Your scheme for propelling vessels against the stream is very ingenious. Altho' you have not been aware of it and have equal merit as an inventor, it was tried in France many years ago. If you refer to a Book entitled *Machines approuvées par l'Académie des Sciences* you will find four schemes proposed.

. . . . . .

I have given you these in detail that you may be able to judge whether your scheme is similar. If so, as I said before, I do not consider that it lessens your merit as a discoverer in the slightest degree. There is one thing it may however prove, the great difficulty of hitting upon any useful scheme that has not been previously attempted, and the necessity of examining well before one expends time on such occupations.

Indeed were I you, and I am sure you will excuse me as a senior apprentice, I would, for the present, avoid all attempts at inventing machinery of any description.

After a few years have gone round and you have become well acquainted with the principles of mechanism and with the discoveries and *failures* of others, you will be able to bring a mind well stored to the task, and from knowing the wants of practical Science be able also to fill them up.

It seems to me to be nearly as great a waste of time, making attempts at *useful* discovery without this previous knowledge, as for a person to labour at working out the highest problems in Astronomy without having first gone through the Calculus.

I cannot avoid speaking feelingly, my dear James, upon this subject, as I lost a great deal of time and spent money on making a rotatory steam engine, which, when finished, I found had been patented ten years before.

. . . . . .

Believe me my dear James Yours sincerely

J. R. McClean."

In 1842, having considerably improved in health, Thomson went for some time to Walsall (not as a pupil nor as an *employé*, but simply as a friend) to learn what he could by practical experience under Mr McClean's guidance.

Early in 1843 he went to the Horsely Iron Works, Tipton, Staffordshire, where he remained for a few months as a pupil in

* The first Chair of Engineering in the United Kingdom, probably the first in the world, was that founded by Queen Victoria in 1840 in the University of Glasgow. Lewis D. B. Gordon held it from 1840 to 1855, and James Thomson was a student in his class of 1841—2.

the drawing office. In August, to his great satisfaction, he was apprenticed to Mr (afterwards Sir William) Fairbairn, his father paying £100 as his apprenticeship fee, and he began working in Fairbairn's Engine Works at Millwall, London. Messrs Wm. Fairbairn & Co. were well known as the first millwrights and among the first engine makers in Britain.

McClean in writing to congratulate him says "I have always considered your health as the only obstacle to your being a first rate practical engineer. I feel confident that you have the talent for it."

Unfortunately his health was not equal to the strain of working in the damp unhealthy surroundings at Millwall. He suffered from continual colds as shown by the following extracts from his letters to his father.

"MILLWALL, *Oct.* 8, 1843.

The Isle of Dogs I find is a very unhealthy place; and the workmen are often obliged to leave it soon after they come, on that account. The ground is low and marshy, and a kind of rank smelling fog rises for several feet from it in the evenings. I have had a cold now for some weeks, and have been coughing a little in the mornings, but not nearly so much as when I went down to Southannan*; and I think that when I get to my new lodgings, by wearing plenty of clothes and staying in the house almost entirely after work hours I shall be able to get on quite well."

"MILLWALL, *Oct.* 10, 1843.

Since last Friday I have been taking holidays from the works on account of my cold, and taking quick walks (half walking and half running) with a great deal of muffling. In this way my cold is now beginning to get better, and I think that in a few days more I shall be able to go back to the works. In the house I am reading the Hot Blast Trial, which is I think the most useful book I could have on Engineering.

. . . . . .

I am very glad to hear that the Algebra has been getting on so well. You must let the Trigonometry wait for a while, as it would keep you too busy when the Session begins. One of the workmen with whom I have had some conversation, as he worked beside me for some time, asked me to recommend him some simple book on mensuration; so I lent him your Arithmetic on account of the article in it on mensuration. He has been greatly taken with it, and has been sometimes sitting up late at night and

* Southannan was an interesting old house on the Clyde which Dr Thomson had rented for summer quarters that year.

sometimes rising at 4 or 5 in the morning to read about fractions, common multiple, proportion, square root, cube root, &c. and to do the examples and exercises."

"MILLWALL, *Nov.* 24, 1843.

I cannot say that it [my cold] is getting better yet, although I have now been away from the works a fortnight and four days, and have been taking all the care I could."

While he was working at Millwall he was interested in a method for preventing smoke in furnaces, which he had thought of. The gases were to be taken downwards through the furnace instead of upwards; and the fire-bars were to be tubes with water circulating through them.

In October 1844 James Thomson was transferred to Messrs Fairbairn's Manchester Works, a welcome change, seeing that it afforded more opportunities for personal intercourse with Mr William Fairbairn who lived there. He moved into lodgings from which he wrote to his father "One might as well live in a chimney as live near the Works." He remained in the fitting shop until ill-health interrupted his progress in his profession. There was some derangement of the heart's action; his pulse beat too quickly—as much as 120 a minute—and he felt weak and ill. He wrote to his father, "I confess I feel very uneasy about it. I wonder if there is any likelihood of my getting stronger as long as it [the pulse] continues to go so fast as it has been lately or if it is likely to begin to go slower."

At the end of the year he returned home to Glasgow; his medical adviser there, a stern old Calvinist, told him he had heart-disease and might die at any moment, and advised him to put away from his mind all thoughts of this life and prepare himself for the other world. Happily this diagnosis turned out to be wrong. The distressing symptoms were the result of temporary disturbance. After some years he completely recovered his health, and was able during the remainder of his long life to enjoy active exertion both of mind and body. But at the time the verdict seemed a death sentence, and the effect on a man of twenty-three, at the very commencement of his career, might easily have been to render him a complete invalid. Happily his natural energy saved him from this, and when bodily exertion was prohibited, he